Fundamentals of Medical Imaging

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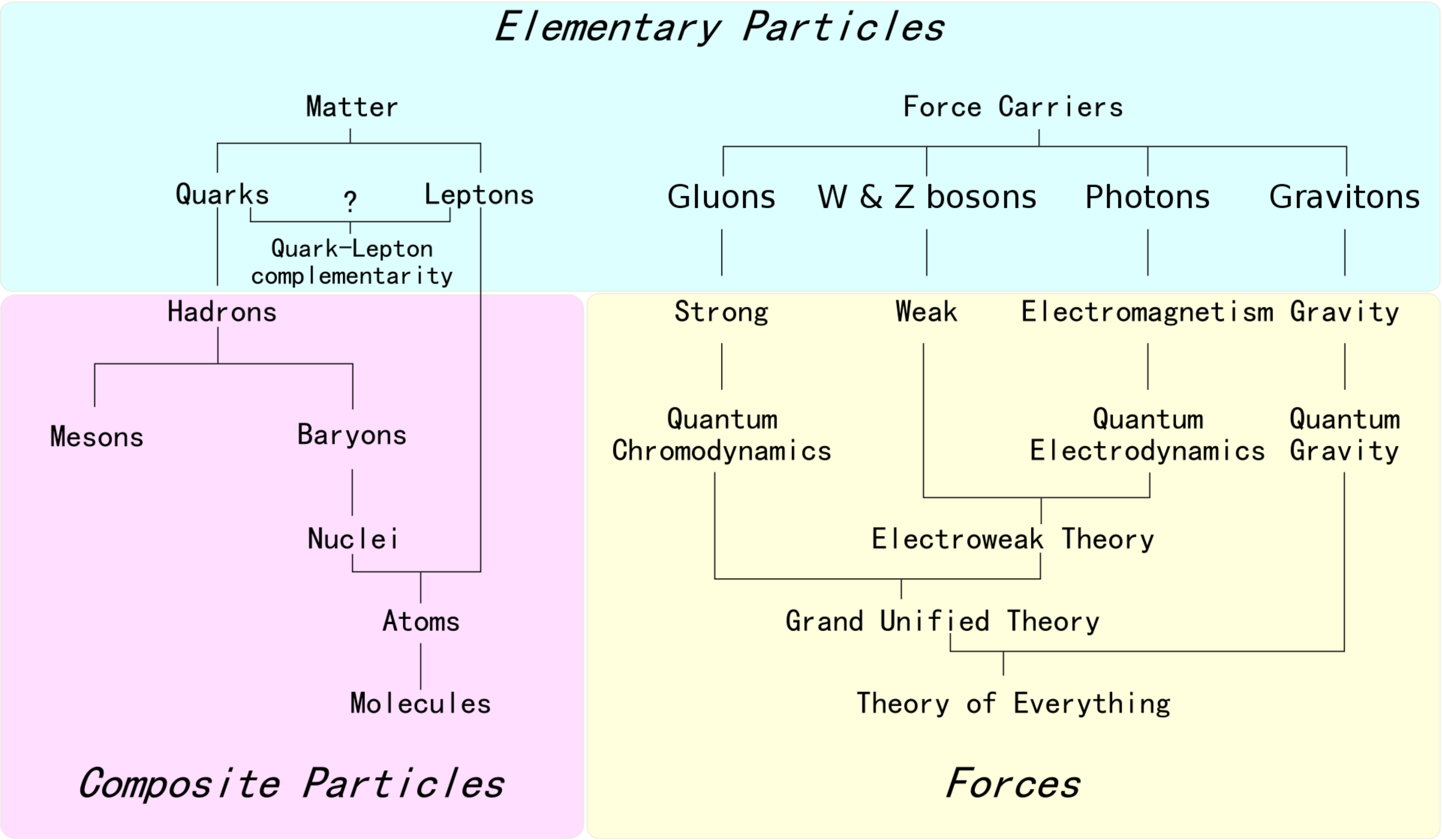
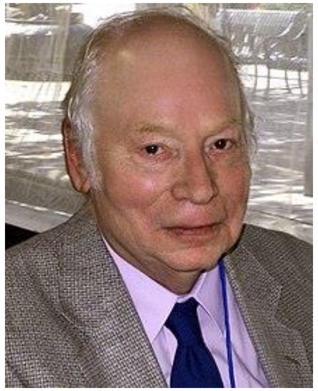
Fundamental interaction



Sheldon Glashow

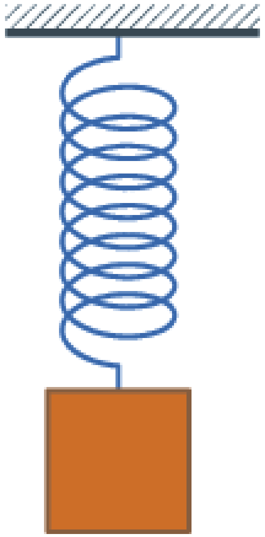
Abdus Salam

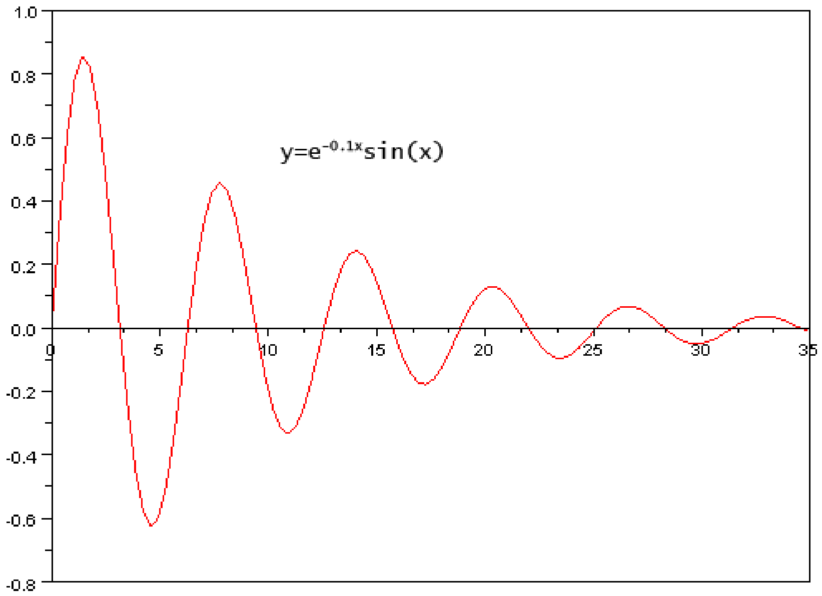


Steven Weinberg

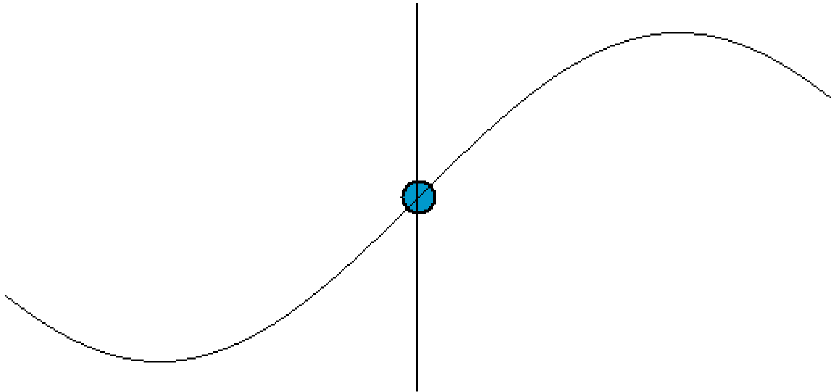
Oscillations

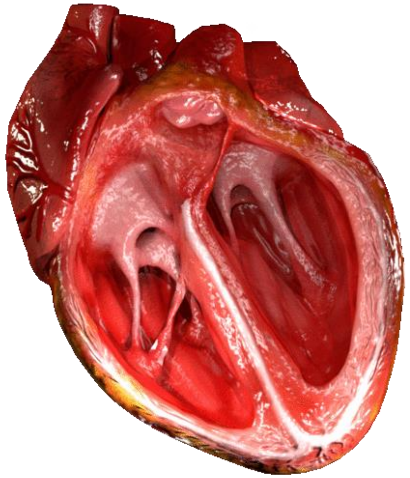
Harmonic oscillations





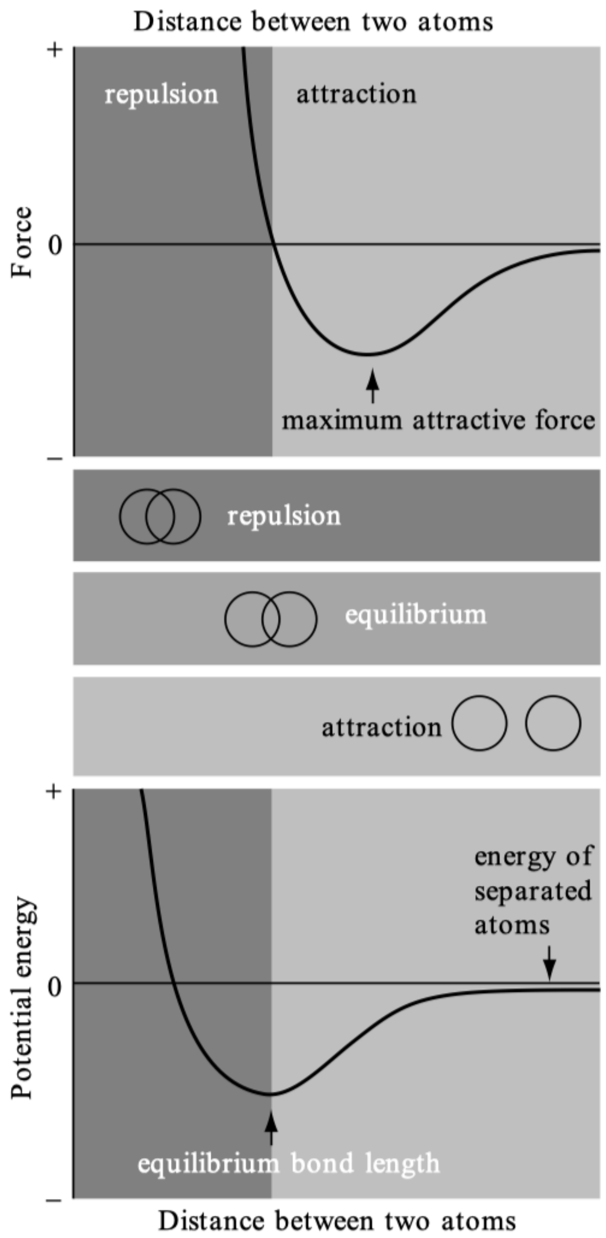
Damping oscillations





Forced oscillations

Oscillation mechanism

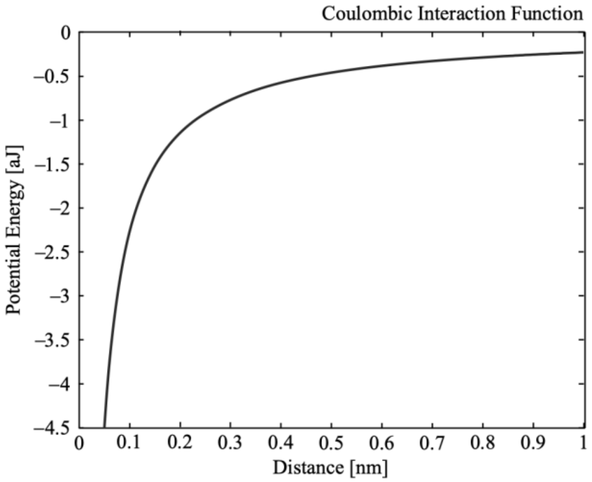


Graphical representation of the relationship between the force between two atoms and the distance between them

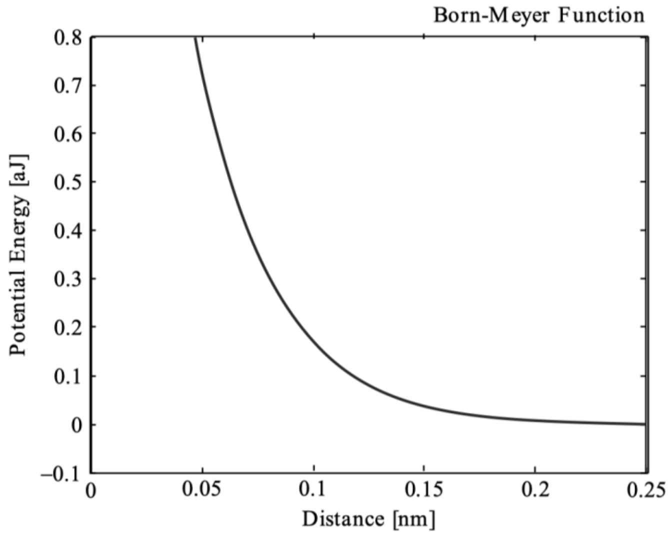
The atoms of a substance vibrate continuously, which on the one hand is caused by the circular motion of electrons around the atom, on the other hand by the change of the distance between the atoms.

It is the distance between the atoms of a substance, the type of interaction, determine the aggregate states of the substance.

Attraction



Repulsive

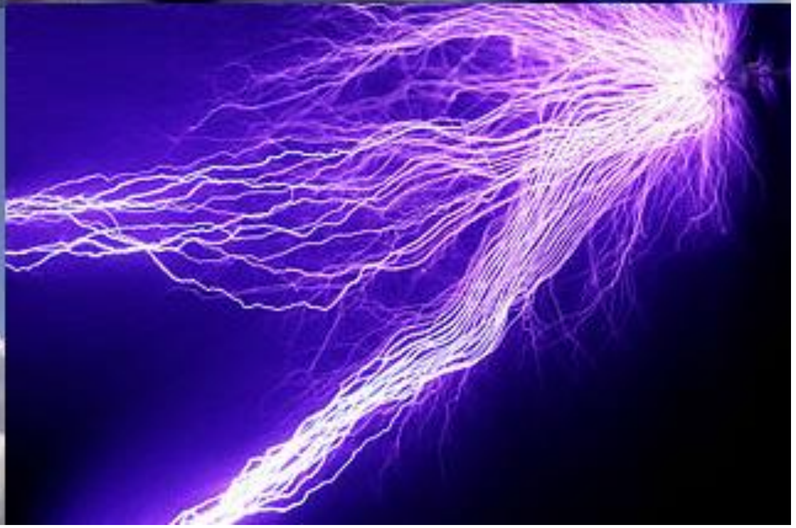


Aggregate states

solid

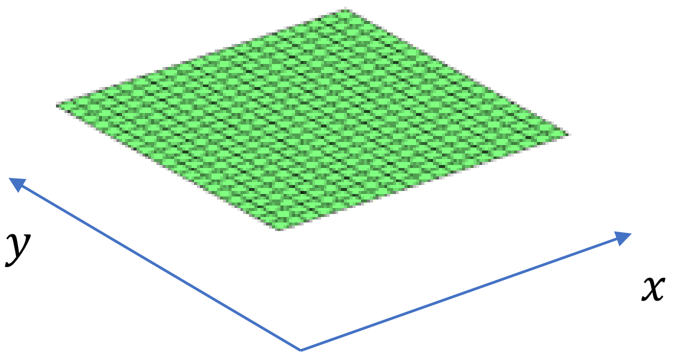
liquid

gas

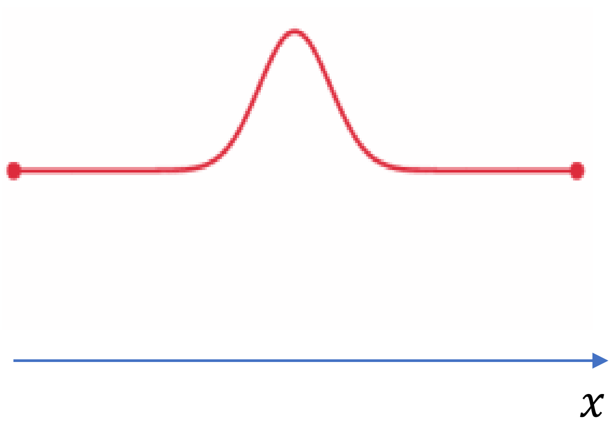


plasma

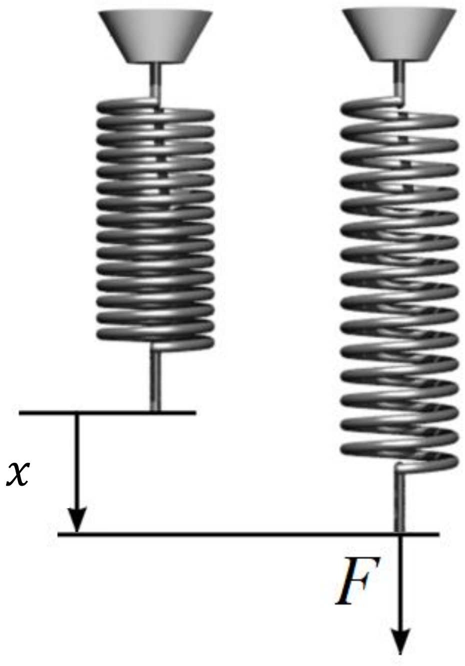
Waves



$$\frac{\partial^2 u}{\partial t^2} = c^2\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right)$$



$$\frac{\partial^2 u}{\partial t^2} = c^2 \frac{\partial^2 u}{\partial x^2}$$



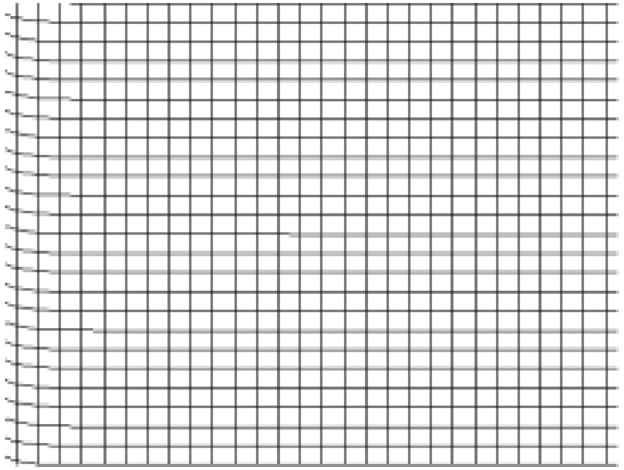
$$k = \frac{F}{x}$$

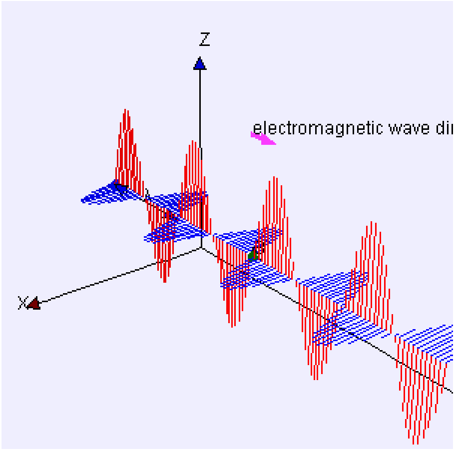
Elastic modulus is a property of the constituent material; stiffness is a property of a structure or component of a structure, and hence it is dependent upon various physical dimensions that describe that component.

$$k = E\frac{S}{L}$$

Waves types

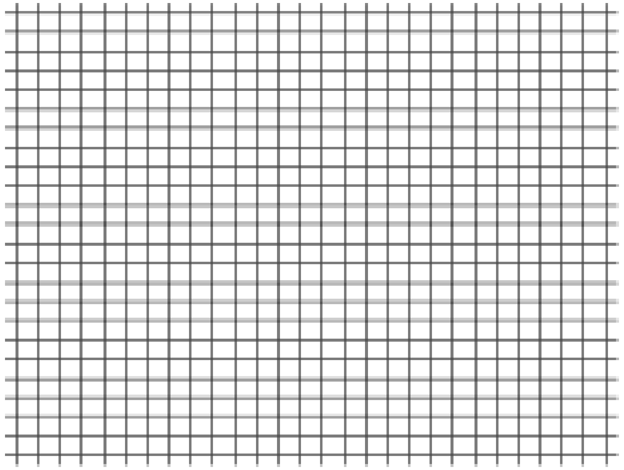
Mechanical wave

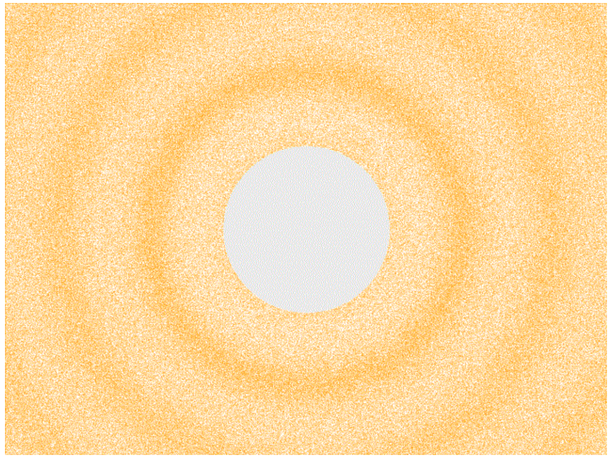




A transverse wave is a wave whose oscillations are perpendicular to the direction of the wave's advance.

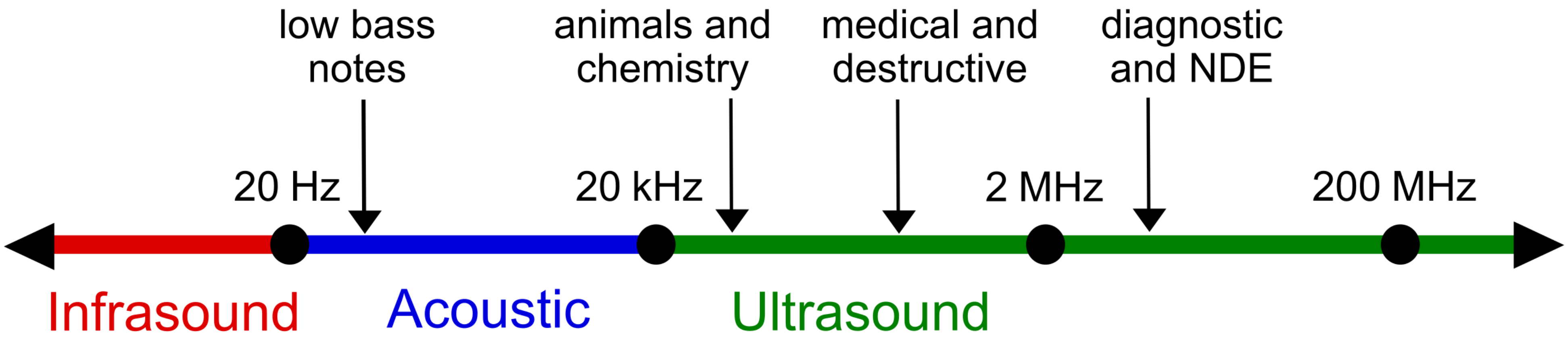
Electromagnetic wave





A longitudinal wave which travels in the direction of its oscillations.

Acoustic waves



$$I = pv$$

$$L_I = \frac{1}{2}\ln\left(\frac{I}{I_0}\right)\,\mathrm{Np} = \log_{10}\left(\frac{I}{I_0}\right)\,\mathrm{B} = 10\log_{10}\left(\frac{I}{I_0}\right)\,\mathrm{dB},$$

$$I_0 = 10^{-12}\ W/m^2$$

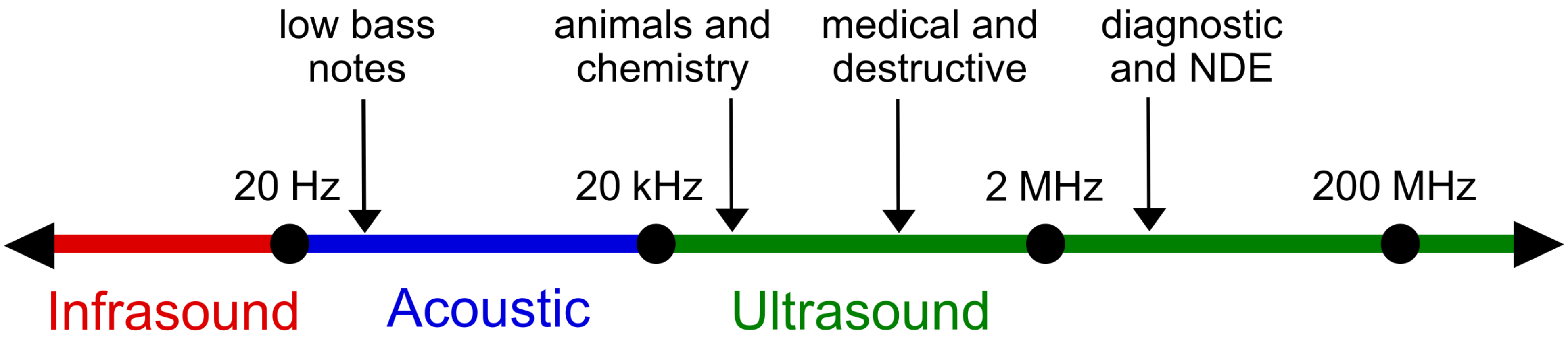
$$\frac{I}{I_0} = \frac{p^2}{p_0^2},$$

$$p_0 = 2 \cdot 10^5\ Pa$$

Intensity dB	Please
0-20	Underground quite place
20-40	Bedroom
40-60	Siting room
60-80	Street
80-100	Factory
100-120	Explosion

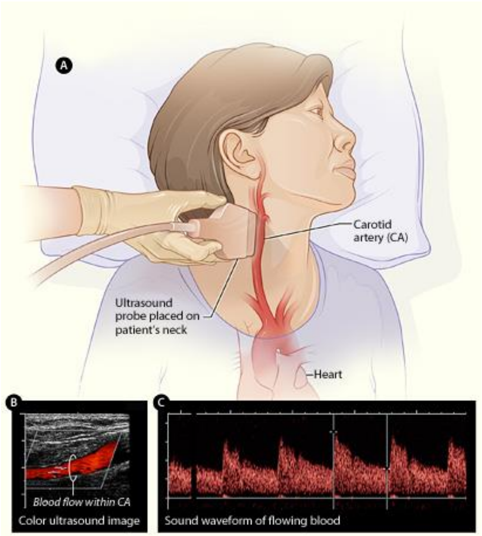
Acoustic waves

Some examples of ultrasound



Bats use ultrasounds to navigate in the darkness

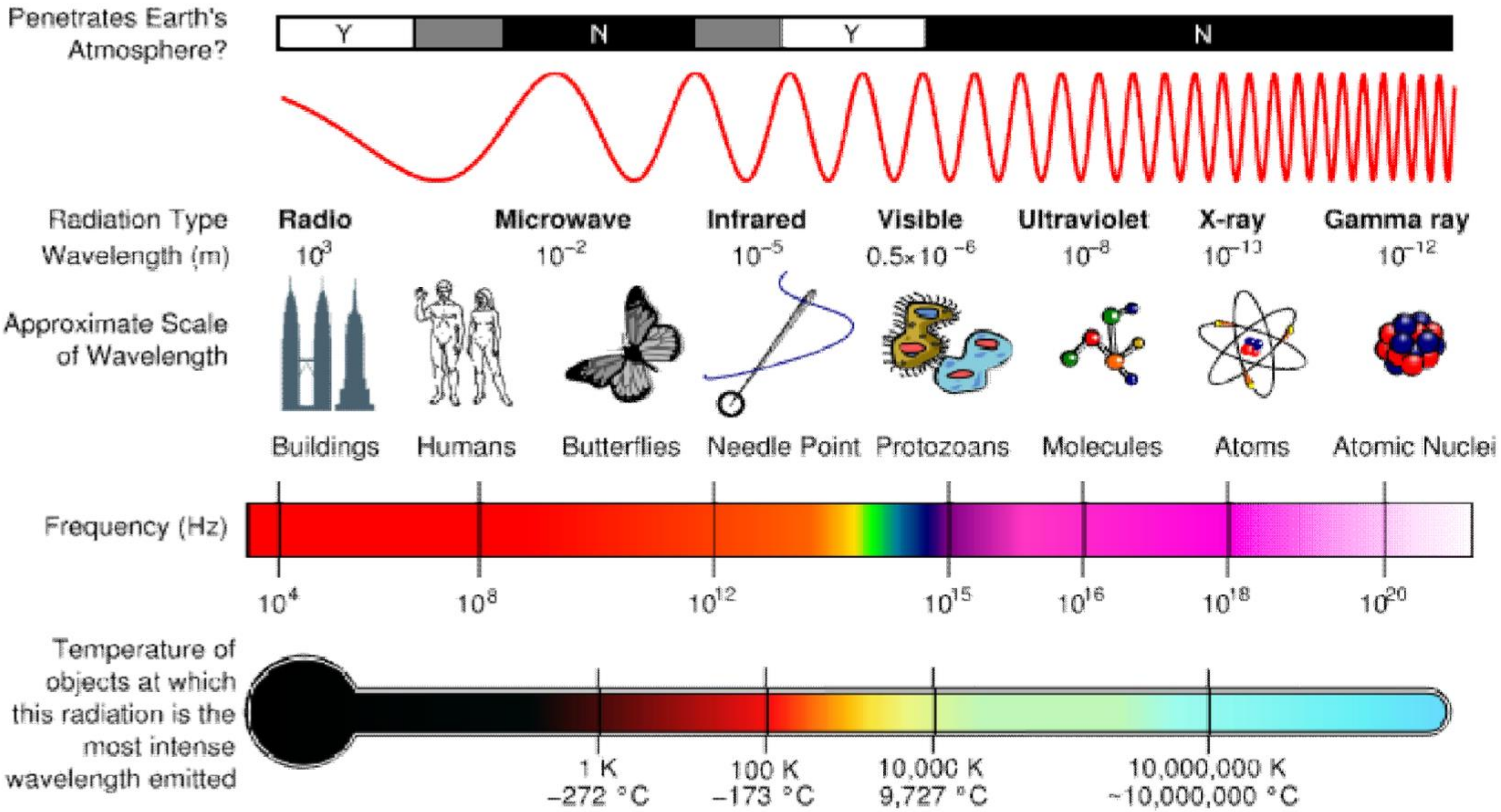
Ultrasound of human heart showing the four chambers and mitral and tricuspid valves.



Ultrasound of carotid artery

Sonographer doing echocardiography on a child

Electromagnetic radiation

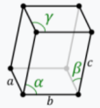
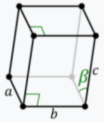
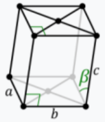
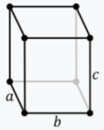
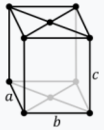
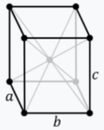
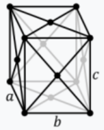
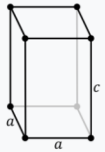
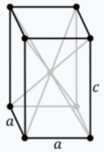
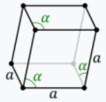
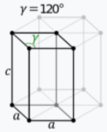
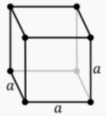
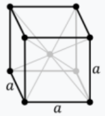
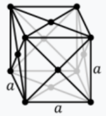


Principles of crystallographic

System	Defining characteristics	Space lattices	Examples
Cubic	Three axes at right angles, all equal in length.	Simple	Cesium chloride
		Body-centered	Sodium
		Face-centered	Copper
Hexagonal	Two equal axes subtend 120° angle, each at right angles to third axis of different length.	Simple	Zinc
Tetragonal	Three axes at right angles, two of equal length.	Simple	Barium titanium oxide
		Body-centered	Indium
Trigonal (rhombohedral)	Three equally inclined axes, not at right angles, all equal in length.	Simple	Calcite
Orthorhombic	Three axes at right angles, all of different lengths.	Simple	Lithium formate monohydrate
		Base-centered	Uranium
		Body-centered	Sodium nitrite
		Face-centered	Sodium sulfate
Monoclinic	Three axes, one pair not at right angles, all of different lengths.	Simple	Lithium sulfate
		Base-centered	Tin fluoride
Triclinic	Three axes, all at different angles, none of which is a right angle, all of different lengths.	Simple	Potassium dichromate

The seven crystal systems and fourteen space lattices

Crystal Structure = Lattice + Basis

Crystal family	Lattice system	Point group (Schönflies notation)	14 Bravais lattices			
			Primitive (P)	Base-centered (S)	Body-centered (I)	Face-centered (F)
Triclinic (a)		C_i	 aP			
Monoclinic (m)		C_{2h}	 mP	 mS		
Orthorhombic (o)		D_{2h}	 oP	 oS	 oI	 oF
Tetragonal (t)		D_{4h}	 tP		 tI	
Hexagonal (h)	Rhombohedral	D_{3d}	 hR			
	Hexagonal	D_{6h}	 hP			
Cubic (c)		O_h	 cP		 cI	 cF

Principles of crystallographic

$$\boldsymbol{r}_n = n_1\boldsymbol{a} + n_2\boldsymbol{b} + n_3\boldsymbol{c}$$

$$d_{hkl} = \left(\frac{h^2}{a^2} + \frac{k^2}{b^2} + \frac{l^2}{c^2}\right)^{-1/2}$$

$$\rho_\phi = \sum_{n=-\infty}^{\infty} K_n e^{in\phi}$$

$$A = A_0 \frac{q_e^2}{m_e c^2 r} \sin\chi$$

$$f = \int \rho_e(r) e^{-i\phi} dV$$

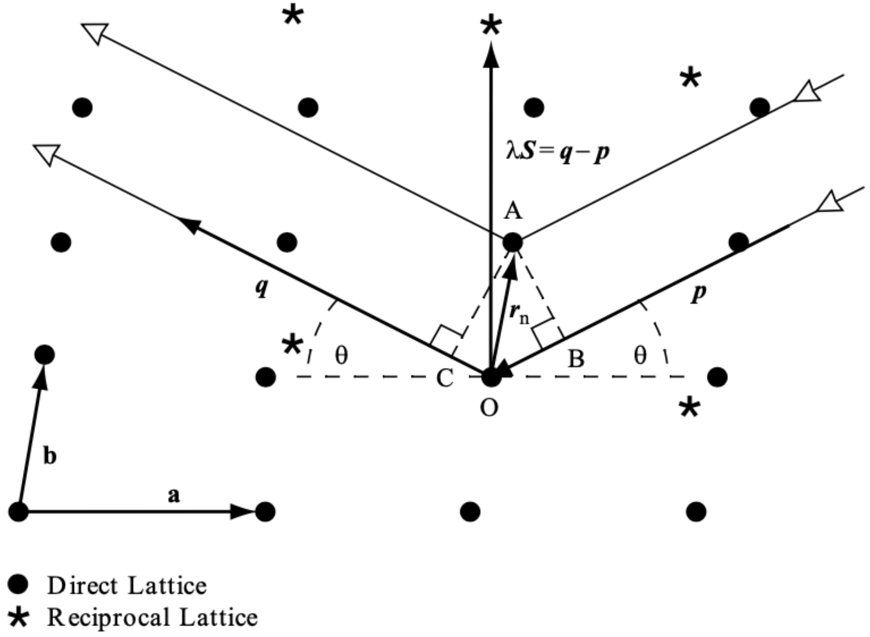
$$\Psi(r, t) = A\,e^{-i(\omega t - \boldsymbol{k}\cdot\boldsymbol{r})}$$

X-ray diffraction to the study of biological molecules lies in its ability to yield information about the arrangement of atoms within the molecule

$$f(\boldsymbol{q}) = \int \rho_e(r) e^{i\boldsymbol{q}\cdot\boldsymbol{r}} dV \;\Rightarrow\; \rho_e(r) = \frac{1}{(2\pi)^3}\int f(\boldsymbol{q}) e^{i\boldsymbol{q}\cdot\boldsymbol{r}} d^3q$$

$$f(0) = \int \rho_e(r) dV = Z \;\Leftarrow\; \phi = 0$$

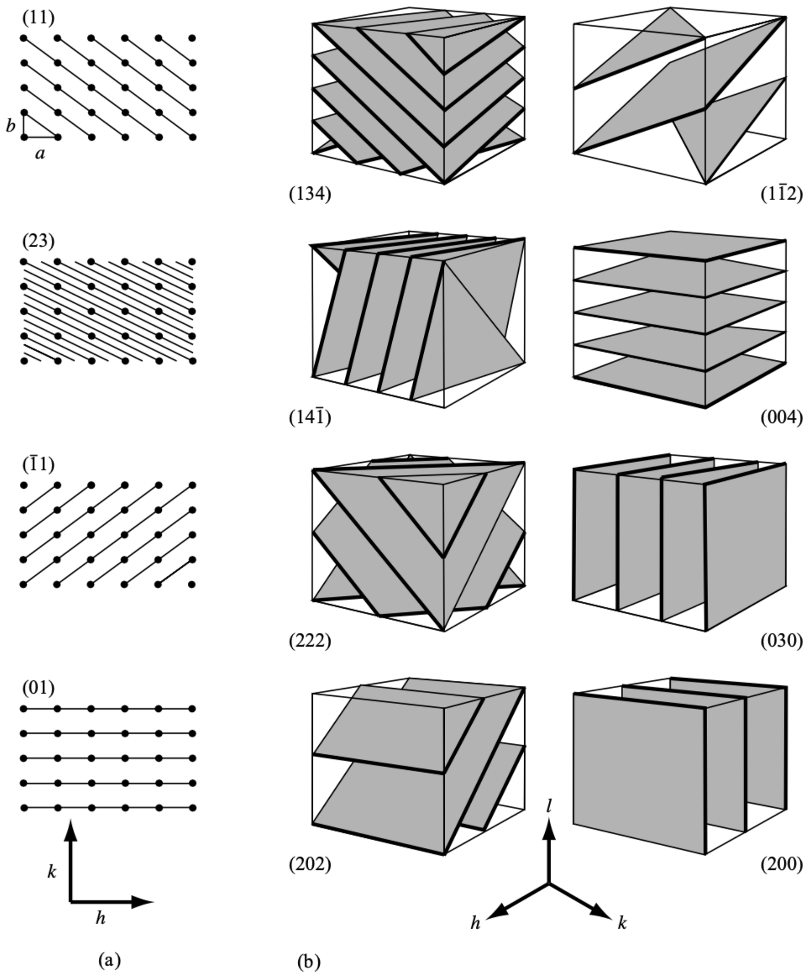
Calculation of parts difference in direct the direct lattice for rays scattered of the origin (O) and at $\mathbf{r}_n$ (A), together with the corresponding reciprocal lattice and the derivation of Bragg's law



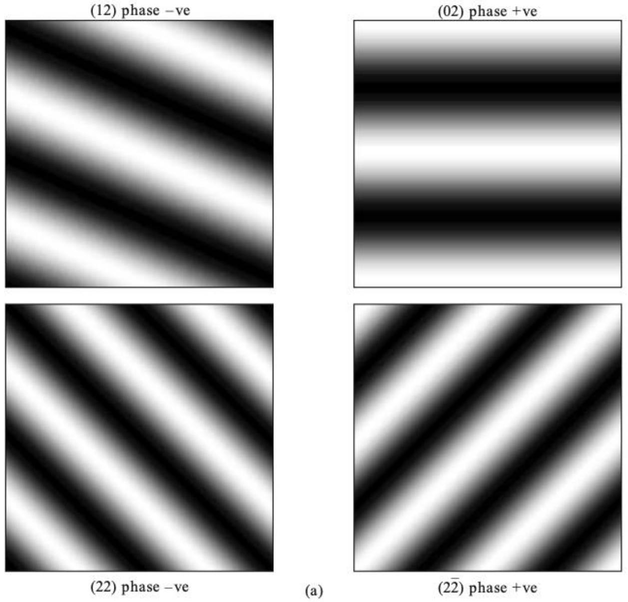
Principles of crystallographic

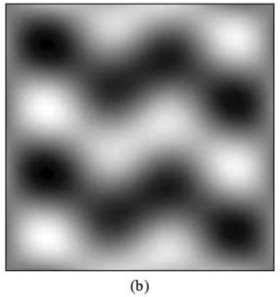
$$\lambda = 2d_{hkl}\sin\theta$$

$$F_{hkl} = |F_{hkl}|e^{i\alpha(hkl)} = \frac{V}{abc}\int_{-a/2}^{a/2}\int_{-b/2}^{b/2}\int_{-c/2}^{c/2}\rho(x,y,z)e^{2\pi i(hx/a+ky/b+lz/c)}dxdydz$$



Examples of the arrangement of lines (a) and planes (b) corresponding to the Miller indices of various sets of parallel lines in a two-dimensional lattice (hk in a) and various sets of parallel planes in a three-dimensional lattice (hkl in b).





The application of Fourier synthesis to the determination of crystal structure is illustrated in this grossly simplified two-dimensional analogue. We assume that there were only four (equally intense) diffraction spots with non-zero intensity, and the sinusoidal alternations show the Fourier components corresponding totheir Miller indices and phases. These four plots were superimposed to produce the final picture shown at the bottom. In practice, the various F ourier components would be superimposed with different exposures, because of the varying intensities of the diffraction spots, of which there would be several hundred or more

Nuclear Magnetic Resonance

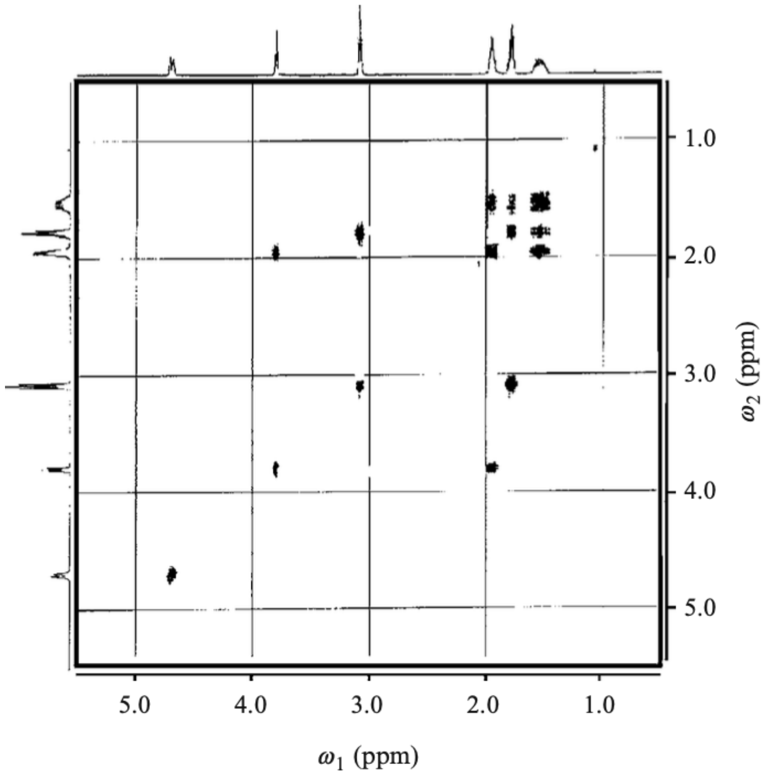
The nuclear magnetic resonance technique was developed through the collective efforts of **Isidor Rabi**, **Felix Bloch** and **Edward Purcell.**
NMR stems from the dependence of this coupling to the surrounding environment, the energy absorption characteristics being exquisitely sensitive to the local magnetic neighbourhood. The local variations in the degree of coupling gives rise to what are known as chemical shifts, and the complexity of the observed spectra increases with increasing molecular size.

$$d\boldsymbol{\mu}/dt = \gamma(\boldsymbol{\mu} \times \boldsymbol{H})$$

$$\boldsymbol{\mu} = \gamma \boldsymbol{L}$$

$$\omega = \gamma H$$

$$S(\omega) = \frac{A\tau_2}{1 + \tau_2^2(\omega - \omega_0)^2}$$



500 MHz two-dimensional NMR correlation (COSY) spectrum of Lysine in D2O. The ω_1 and ω_2 axes correspond to the Fourier transforms of the two pulse durations, and the prominent diagonal corresponds to resonances in the one-dimensional spectrum (shown along two orthogonal sides).

Exercise

1. Download the app “sound meter” or any other similar program on your smartphones and determine the noise level of different points of in present room.
2. Foucault's pendulum is installed in the second building of BSU as part of a student project. Determine the deflection angle of the Foucault pendulum 10 minutes after the deflection